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A Study of Kerosene Cook Stoves

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AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 48

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SUMMARY

The purpose of this study was to learn the advantages and disadvantages of various types of kerosene cook stoves used in Nebraska.

TYPES OF STOVES STUDIED

Kerosene cook stoves have burners of four types. Ten stoves representing the four types were studied as follows: four stoves having long-chimney wick burners; three stoves having short-chimney wick burners; two stoves having short chimneys with asbestos kindlers or lighting rings; one stove having wickless burners.

STUDIES MADE ON FOUR TYPES OF BURNERS

To determine comparative performance of the four types of burners, they were tested for: (1) time required to heat a known quantity of water thru a known range of temperature; (2) thermal efficiency, which is defined as the ratio of the heat units absorbed by the cooking process to the heat units liberated by the kerosene; (3) time required to cool; (4) tendency to form soot on utensil; (5) practical use under home conditions.

TIME REQUIRED FOR HEATING

To determine comparative speed of burners, equal quantities of water were heated thru equal ranges of temperature. The tests were made by two methods: (1) the "cold start", in which the time required to heat the water after the lighting of the cold burner was determined; and (2) the "hot start", in which the time was determined with the burner fully heated at the beginning of the test.

Data presented in this bulletin on comparative heating time of different types of burners selected for this study show that by the "cold start" method the average time required to heat the water by all long-chimney wick burners, adjusted as directed for maximum heat, was significantly less than averages for other types. The time required by one short-chimney burner studied was less than that of one long-chimney burner. The wickless burner required the longest to heat of the four types.

By the "hot start" method, the average time required to heat the water was approximately equal for burners with wicks; the average time required by burners with lighting rings and by wickless burners was greater than by those with wicks. The wickless required the longest time. Some differences in speed of heating of individual burners of the same type were greater than average differences for groups of different types.

Giant burners studied required less time to heat the water than standard burners on the same stove.

Burners covered with heavy grates required a longer time to heat the water than burners covered by open grates.

TIME OF COOLING

Burners with wicks cooled more rapidly than other types. The wickless burners held heat longest.

THERMAL EFFICIENCY OF BURNERS

To determine the comparative thermal efficiency of burners, equal amounts of water, at the same initial temperature, were completely evaporated, and the amount of kerosene used was determined.

Data presented on comparative thermal efficiency of burners selected for this study show that the average thermal efficiency of all long-chimney wick burners was lower than that of burners of other types. The average thermal efficiency of short-chimney wick burners was highest of the four types. One burner of the short-chimney lighting-ring type was higher in thermal efficiency than the average for short chimneys with wicks. The wickless burner was higher in thermal efficiency than long-chimney burners, but lower than the two remaining types.

Standard burners were higher in thermal efficiency than giant burners on the same stove.

FORMATION OF SOOT

Long-chimney burners adjusted as directed by the manufacturer for maximum heat, that is, with yellow tips 1½ inches above the blue flame, did not form soot on utensils. Other types of burners formed soot frequently. Because of the contact of the flame with the utensil, these burners are more likely to be affected by outside factors, causing soot to be formed.

EFFECT OF SIZE OF UTENSIL

To learn the effect of the size of utensil on the performance of burners, water was heated thru equal ranges of temperature in pans of equal depth but varying in diameter. Giant and standard burners on the same stove were used for the tests. Records were kept of the time required to heat the water and of the oil consumed. Data presented show that (1) as diameter of pan increased thermal efficiency increased, reaching a maximum at the largest pans, and (2) as diameter of pan increased time per pound required to heat it thru a given range of temperature decreased, reaching a minimum at the largest pans.

The practical significance of these results is that for every burner there is a definite size of utensil which can be used to best advantage. From the standpoint of economy of time and fuel utensils should in general be fairly large.

PRACTICAL USE OF BURNERS

To determine comparative cost of operation and time used for the cooking of food with different types of burners, a week's menus for six persons were cooked on four selected stoves representing the different burner types. The burners were operated so as to use the minimum amount of time and oil.

Data presented show that the long-chimney burner, over a week's time, used the greatest amount of kerosene. The short-chimney wick burner used the least kerosene of the four types. The total cost of operation, including wicks, lighting rings, and gasoline for priming the wickless burner, was highest for the long-chimney wick burner. For the wickless burner the total cost was slightly less than for the long-chimney wick burner. The total costs for the short-chimney with wick and the lighting-ring burners were lowest and approximately equal.

Time required in burner hours was approximately equal for the long-chimney wick burner and the burner with lighting ring. The time required by the wickless burner was greatest of the four types.

The burners with wicks were more quickly and easily adjusted for varying degrees of temperature for cooking purposes than were the other types of burners.

A Study of Kerosene Cook Stoves

EDNA B. SNYDER [1]

Kerosene cook stoves are widely used in Nebraska rural homes, and until gas is brought within reach or electric power becomes cheap enough to compete with other fuels, kerosene will continue to be the chief fuel during the summer months. There is little exact information available concerning the relative merits of the various kerosene cook stoves offered on the market. This study was undertaken to learn the advantages and disadvantages of the different stoves sold in Nebraska.

Any kerosene burner, to give satisfactory service, should meet the following requirements: (a) it should be quick to develop a steady flow of heat; (b) it should perform the operations of heating rapidly; (c) it should not be extravagant in the use of fuels; (d) its provision for draft should be such that the fuel is completely oxidized to prevent objectionable odor and the formation of soot; (e) the burner should be simple to operate and easy to clean. In this bulletin are reported studies on: (a) time of heating; (b) thermal efficiency, which is defined as the ratio of the heat units absorbed by the cooking process to the heat units liberated by the kerosene; (c) tendency to form soot on utensils; (d) the relation of size of utensil to performance of burners; and (e) practical use, under home conditions.

TYPES OF STOVES STUDIED

Ten stoves, differing in major constructional features as listed below, were selected and purchased for study. All of these are stoves rather widely advertised and sold in Nebraska. One stove was purchased from a leading mail order house.

(a) Four stoves studied have long-chimney burners with wicks.
(b) Three stoves have short-chimney burners with wicks.
(c) Two stoves have short-chimney burners with asbestos kindlers or lighting rings.
(d) One stove has wickless burners.

Some differences in frame construction affecting the performance of the burners are as follows:

(a) The burners on one stove selected are covered with heavy iron tops or grates, similar to those on coal stoves, except that there are openings directly over the flame.

(b) The stove with the heavy iron top and another with a lighter weight top have draft spaces back of the burners,

[1] This project was outlined by Dr. Greta Gray, now Associate Professor of Home Economics in the University of California, at Los Angeles. Dr. Gray selected several of the stoves studied and supervised the preliminary work on the project.

under the rear of the top, to be used for slow cooking and for keeping food hot. These spaces are enclosed so that the surplus heated air from the burner is retained.

(c) Burners on the remaining eight stoves are covered by open grates similar to those commonly used on gas stoves.

(d) Three of the stoves have both giant and standard burners. The diameter of a giant burner exceeds that of a standard, on the same stove, generally 1 to 2 inches, the difference varying on different makes of stoves.

Table 1 shows stoves included in the study, grouped as to type of burner, and also lists other constructional features.

TABLE 1.—*Stoves included in the study, grouped as to type of burner, and other important constructional features*

Type of burner	Number of burners on stove		Diameter of burners		Kind of grate over burner	Draft spaces back of burner
	Standard	Giant	Standard	Giant		
	Number	*Number*	*Inches*	*Inches*		
Long chimney with wick..............	3	0	3 3/8	....	Open	Absent
	3	0	3 3/8	....	Open[1]	Present
	2	0	3 1/2	....	Open	Absent
	4	1	3 3/8	5	Open	Absent
Short chimney with wick..............	3	0	3 3/8	....	Open	Absent
	2	0	2 7/8	....	Open	Absent
	2	2	3 5/8	5	Solid[2]	Present
Short chimney, asbestos lighting ring...............	2	1	4 1/8	5	Open	Absent
	2	0	3 5/8	....	Open	Absent
Wickless	0	3	....	5 3/4	Open	Absent

[1]Small, round, removable, open grate directly over burner, fitting into an otherwise solid top of light-weight material.

[2]Heavy solid tops with openings directly over burner.

Table 2 shows individual burners studied, designated by number, and grouped as to type, with diameters in inches. Thruout the discussion following, the burners will be referred to as in Table 2. The measurements used for diameters of burners are the diameters of the circles bounding the outside of the wick tube, on burners with wicks; and the diameters of the circles bounding the outer edge of the oil trough, for the other types. The diameter of the flame produced is, in wick burners, slightly greater than the diameter of the wick tube.

TABLE 2.—*Numerical designation, type, description, and diameter of burners used in the study*

Number of burner	Type	Diameter
		Inches
No. 1	Long chimney with wick	3 3/8
No. 2	Short chimney with wick	3 3/8
No. 3	Short chimney with wick	2 7/8
No. 4	Long chimney with wick	3 3/8
No. 5	Short chimney with asbestos lighting ring	4 1/8
No. 6	Short chimney with asbestos lighting ring	5
No. 7	Short chimney with wick	3 5/8
No. 8	Short chimney with wick	5
No. 9	Wickless	5 3/4
No. 10	Long chimney with wick	3 1/2
No. 11	Short chimney with asbestos lighting ring	3 5/8
No. 12	Long chimney with wick	3 3/8
No. 13	Long chimney with wick	5

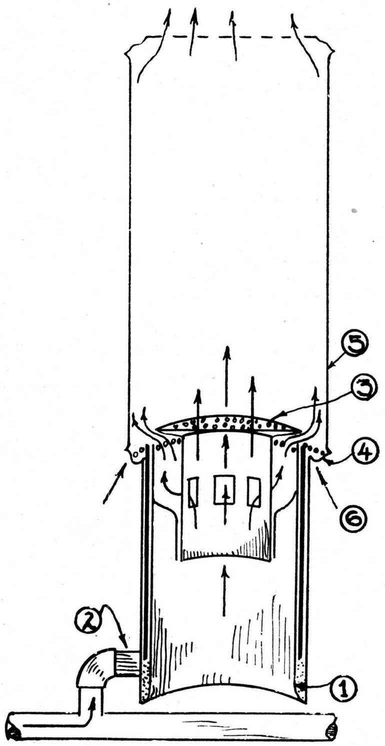

FIGURE 1.—Long-chimney wick burner
1. Double-walled wick tube
2. Feed pipe
3. Flame spreader
4. Collar, on which chimney rests
5. Chimney
6. Arrows showing direction of air currents

DETAILS OF BURNER CONSTRUCTION

The most complicated, and at the same time most important, constructional feature of a kerosene stove is the burner. Figure 1 shows the long-chimney type, represented in this study by four different stoves.

The parts of the burner are: a woven cotton wick and double-walled wick tube, connected with the feed pipe; a flame spreader to admit air, which fits into a support in the center of the wick tube; a collar surrounding the wick-tube, on which the chimney rests; and a drum or chimney, which serves as a combustion chamber, so constructed that when heated an air current passing upward thru it lifts the oil vapor from the wick. With this type of burner the flame is about 10 inches below the utensil.

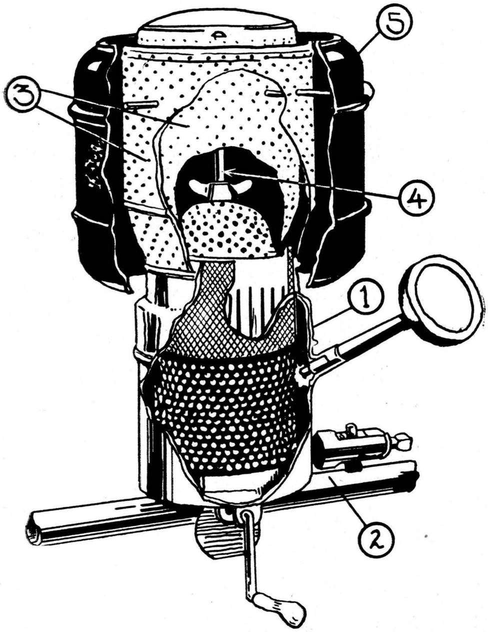

FIGURE 2.—Short-chimney burner with wick

1. Double-walled wick tube
2. Feed pipe
3. Outer and inner combustion tubes
4. Inner support
5. Chimney

Figure 2 shows a burner of the short-chimney wick type, represented by three different stoves.

The parts of the burner are: a woven cotton wick and double-walled wick tube connected to feed pipe; outer and inner combustion tubes, which are joined and perforated to admit air, and which rest on the wick tube and an inner support; and a drum or chimney connected to the combustion tubes. With this type of burner, the flame comes in contact with the utensil.

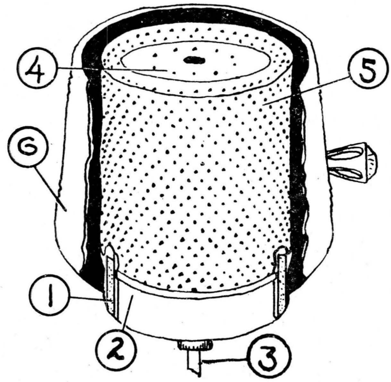

FIGURE 3.—Short-chimney burner using asbestos kindler or lighting ring
1. Asbestos lighting ring or kindler
2. Oil trough or burner bowl
3. Feed pipe
4. Inner combustion tube
5. Outer combustion tube
6. Drum or chimney

Figure 3 shows a burner of the asbestos-kindler or lighting-ring type, represented by two stoves.

The parts of the burner are: an asbestos lighting ring or kindler, which acts as a wick and which rests in a shallow trough or burner bowl, the latter connected to the feed pipe and serving as a container for the kerosene; outer and inner combustion tubes, which are joined and perforated to admit air; and a drum or chimney joined to the combustion tubes. With this type of burner, the flame comes in contact with the utensil.

Figure 4 shows a wickless type of burner, represented by one stove.

The parts of the burner, which are all of iron, are: narrow, shallow troughs into which kerosene flows; metal pieces

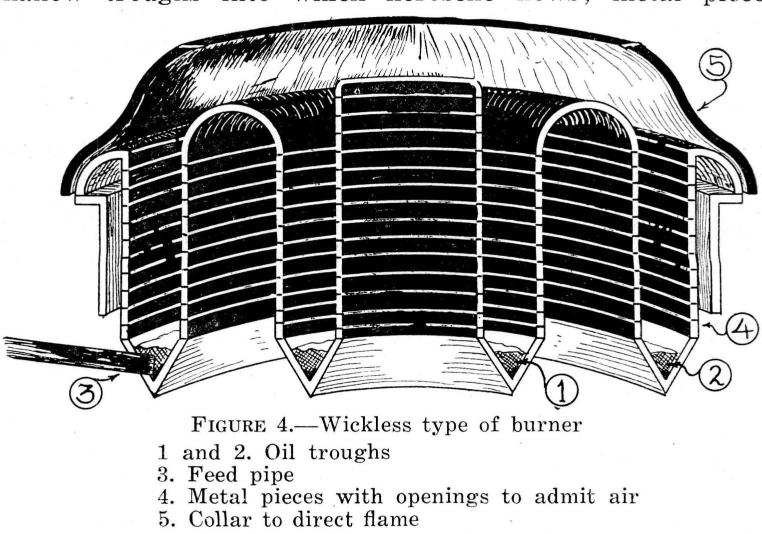

FIGURE 4.—Wickless type of burner
1 and 2. Oil troughs
3. Feed pipe
4. Metal pieces with openings to admit air
5. Collar to direct flame

which rest over the troughs and which have openings to admit air; a collar to direct the flame under the utensil; and a primer which adds alcohol or gasoline in measured amounts, so that the burner can be heated sufficiently to vaporize kerosene. With this type of burner, the flame is very close to the utensil, or just below the grate.

DESCRIPTION OF THE LABORATORY

The ten stoves studied were placed in a laboratory so that conditions might be as nearly uniform as possible. Doors and windows were kept closed during the tests, to prevent draft. The dimensions of the laboratory were 21′ 9″ by 17′ 4″ by 10′ 4″, with 3,899 cubic feet of contents. The room had two windows, 6′ 8″ by 3′ 4″; two doors, 7′ 11″ by 2′ 8½″; and two transoms, 1′ 5″ by 2′ 8½″.

TESTS TO DETERMINE HEATING TIME OF BURNERS

The first set of comparative tests made on the various stoves was a determination of the time required to raise the temperature of four pounds of water from 15° C. to 98° C. (59° F. to 208.4° F.). Ordinary tap water was used. It was heated in covered aluminum pans, uniform in capacity and diameter, of medium thickness, and weighing one pound each. The capacity was 4 quarts and the diameter was 6¾ inches. The burner of each stove was adjusted according to the recommendations of its manufacturer. The time was measured by a stop watch.

The tests were conducted in two ways. In the first, called the "cold start" test, the time was determined from the instant the cold burner was lighted. In the second, called the "hot start" test, the burner was allowed to become fully heated, and the flame was fully adjusted before the test was begun. In order to be certain that the "hot start" test was properly made and at the same time determine how long it took the burners to develop maximum rapidity of heating, the heating of a second quantity of water was begun the instant the cold test was complete, and so on until the time to raise the temperature by 10-degree intervals was uniform.

Figure 5 shows typical data on the rate of heating by the four types of burners of successive four-pound quantities of water, starting with the lighting of the burner (curve 1) and continuing until the rate of heating had reached a steady maximum (curves 3, 4, or 5). In these tests the initial temperature was 30° C., and the water was heated to 98° C. (86° F. to 208.4° F.). The curves for No. 1, a long-chimney burner with wick, show that this burner heated most rapidly and uniformly, and was at full heat when the first quantity

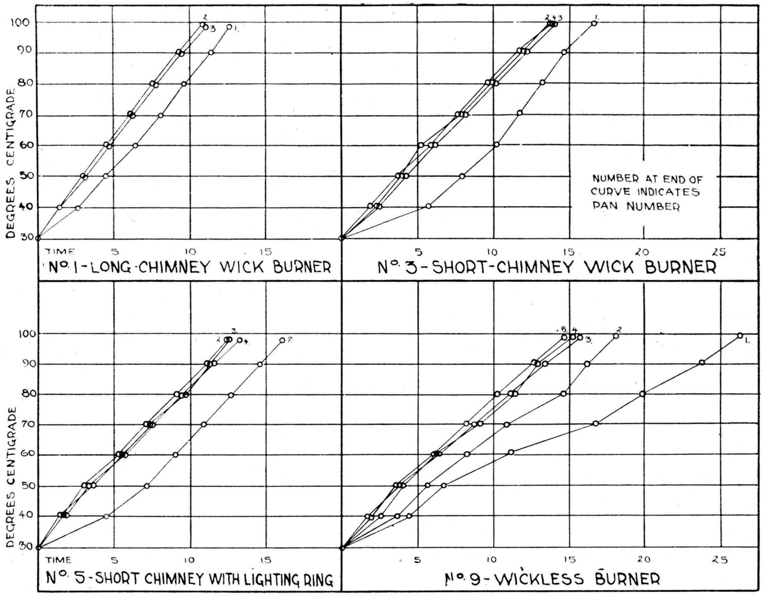

FIGURE 5.—Time required by four selected burners for the development of maximum rate of heating

of water was replaced by the second. The difference in time required for heating the first and the second quantity of water was about 2 minutes.

The curves for burner No. 3, a short-chimney burner with wick, show that this burner heated more slowly than No. 1, but had reached steady heat when the first quantity of water was replaced by the second. The difference between the time required for heating the first and the second quantity was about 3 minutes.

The curves for burner No. 5, a short-chimney burner with asbestos lighting ring, are similar to those for No. 3. The difference between the time required for heating the first and the second quantity of water was slightly greater than for No. 3.

The curves for No. 9, a wickless burner, show that this burner was slowest and least uniform in rate of heating of the four types. The time necessary to heat the water decreased slightly more than 12 minutes between the first and the second quantity; 2¼ minutes between the second and the third; and there was a slight decrease in time, up to and including the fifth.

TIME REQUIRED FOR STANDARD BURNERS TO HEAT

Table 3 shows the time required by each standard burner studied to raise the temperature of four pounds of water from 15° C. to 98° C. (59° F. to 208.4° F.) by both the "cold start" and "hot start" methods. The burners are grouped in the table according to type and approximate diameter. In the group which includes the four long-chimney burners with wicks, the diameters are the same except for one burner, which is slightly more than the others. In the group including the three short-chimney burners with wicks, the diameters differ slightly, the greatest diameter being 3/4 inch greater than the least. In the group including the two short-chimney burners with lighting rings, there is a difference of 1/2 inch in diameter. The burners on the stove of the wickless type were all giant; therefore no wickless-type burner is included in the standard-burner groups.

A comparison of time of heating of the burners in the long-chimney wick group shows that Nos. 1 and 12 required significantly less time than the others in both the "cold start" and the "hot start" tests. The chimney on No. 12 is double walled about half way down from the top, with perforations to admit air where the two walls join. The double wall possibly prevents loss of heat. The chimneys on Nos. 1 and 4 are single walled. These burners are quite similar in appearance, but the flame spreaders differ in number and arrangement of perforations for air. No. 10 differs from both of the others in the group in the shape of the chimney. Instead of being a regular cylinder, it is a single-walled cylinder below, 5¾ inches in diameter and 4 inches in height, joined to a single-walled cylinder 4½ inches in diameter by 6 inches in height, above. The flame spreader differs from the others in size and position of perforations for air. This burner was slowest in both the "cold start" and "hot start" tests.

In the short-chimney wick group, No. 3 was slowest in both the "cold" and "hot" start tests. The combustion chambers and chimney of this burner are entirely open at the bottom, and the chimney is rounded from top to bottom rather than cylindrical. No. 2 heated most rapidly of the group in both tests. No. 7 differs from No. 2 in size and arrangement of perforations at the bottom of the combustion chambers, the perforations being smaller. The top of the inner combustion tube on No. 2 is conical in shape, tending to direct the flame under the utensil more uniformly than No. 7, which is flat at the top.

In the short-chimney lighting-ring group, No. 11 heated more rapidly in both tests. The height of the flame in the

TABLE 3.—*Average time required by each standard burner to raise the temperature of four pounds of water from 59° F. to 208.4° F. (15° C. to 98° C.). The burners are grouped according to type.*

Type	Burner	Diameter	Number of tests	Average time required		Probable error of mean[1]		Difference in time required between cold and hot starts	Room temperature		
				Cold start	Hot start	Cold start	Hot start		Highest	Lowest	Mean
		Inches		*Minutes*	*Minutes*			*Minutes*	*Deg. F.*	*Deg. F.*	*Deg. F.*
Long-chimney burner with wick	No. 1	3 3/8	36	15.78	14.01	±0.100	±0.086	1.77	87	64	78
	No. 4	3 3/8	36	16.88	15.31	±0.158	±0.112	1.37	92	62	86
	No. 10	3 1/2	36	17.24	15.06	±0.092	±0.085	2.18	87	74	80
	No. 12	3 3/8	36	15.51	13.58	±0.112	±0.156	1.93	90	69	77
Average of group	......	3.4	..	16.35	14.49	....	....	1.81	..	..	..
Short-chimney burner with wick	No. 2	3 3/8	36	16.98	14.28	±0.093	±0.084	2.70	87	57	77
	No. 3	2 7/8	36	19.35	15.54	±0.141	±0.103	3.81	90	64	79
	No. 7	3 [illegible]/8	36	18.18	14.58	±0.157	±0.123	3.60	92	64	76
Average of group	......	3.29	..	18.17	14.80	....	....	3.37	..	..	..
Short-chimney burner with asbestos lighting ring	No. 5	4 1/8	36	19.25	15.61	±0.116	±0.101	3.64	95	57	79
	No. 11	3 5/8	36	17.57	15.15	±0.129	±0.101	2.42	98	75	84
Average of group	......	3.87	..	18.41	15.38	....	....	3.03	..	..	..

[1]Formula used for calculating probable error of the mean: $E_m = .6745\sqrt{\frac{\Sigma d^2}{n(n-1)}}$ Σd^2 = the sum of the deviations squared and n = the number of observations.

burners of this group is controlled by the amount of oil allowed to flow into the burner bowl. The burner bowl on No. 5 moves up and down with the chimney, increasing or diminishing the amount of oil around the kindler or lighting ring. On the front of the stove is a dial which indicates the depth of oil in the trough. The burner bowl on No. 11 is stationary, the oil entering thru a valve which opens directly from the supply pipe, making it more difficult to gauge the amount of oil turned into the trough. An excess of oil causes the flame to flare around the utensil, heating the water in less time. The burners differ in provision for air. No. 5 has circular openings at the bottom of the chimney, while No. 11 is entirely open.

A comparison of averages of heating time of the different types for the "cold start" tests shows that those with long-chimney wick burners heated most rapidly. However, No. 2, in the short-chimney wick-burner group, was more rapid than No. 10 in the long-chimney group. Averages for the groups including short-chimney wick and short-chimney lighting-ring burners are approximately equal. It will be observed, however, that there are individual differences between burners of the same type as great as average differences between groups of different types.

Differences of heating time between groups of types from the "hot start" were not significant. The wick burners of both types were slightly more rapid than the lighting-ring group. These results are consistent with curves in Figure 5. The difference in heating time between long- and short-chimney burners is due to the more complicated construction of the chimney and combustion chambers on the latter, requiring longer to become fully heated after the "cold start".

TIME REQUIRED FOR GIANT BURNERS TO HEAT

Table 4 shows the time required by each giant burner to raise the temperature of four pounds of water from 15° C. to 98° C. (59° F. to 208.4° F.) both by "cold" and "hot" start methods. The table includes one giant burner of each type. The burners are equal in diameter, except for No. 9, a wickless type, which is ¾ inch greater in diameter than the others. The long-chimney wick burner, No. 13, was most rapid in both "cold" and "hot" starts, exceeding the others considerably. Burner No. 6, short chimney with lighting ring, ranked second in heating time for both tests. No. 8, a short-chimney wick type, was slow in the "cold start" test. This burner is covered by a heavy iron top, preventing direct transfer of heat to utensil. When used with an open top, it

TABLE 4.—*Average time required by each giant burner to raise the temperature of four pounds of water from 15° C. to 98° C. (59° F. to 208.4° F.)*

Type	Burner	Diameter	Number of tests	Average time required		Probable error of mean		Difference in time required between cold and hot starts	Room temperature		
				Cold start	Hot start	Cold start	Hot start		Highest	Lowest	Mean
		Inches		*Minutes*	*Minutes*			*Minutes*	*Deg. F.*	*Deg. F.*	*Deg. F.*
Short chimney with lighting ring...........	No. 6	5	36	18.86	15.06	±0.180	±0.137	3.80	93	70	79
Short chimney with wick..	No. 8	5	36	20.36	16.71	±0.140	±0.130	3.65	98	71	83
Wickless................	No. 9	5 3/4	36	24.94	16.26	±0.256	±0.129	8.68	90	70	79
Long chimney with wick	No. 13	5	36	13.61	11.09	±0.090	±0.061	2.52	95	69	85

was much more rapid. No. 9 was slowest with the "cold" but approximately equal to No. 8 for the "hot" start. This burner is made of heavy iron parts which require a longer time to become hot. The curves in Figure 5 show how much more slowly No. 9 heats than the other types of burners.

RELATION OF DIAMETER OF BURNER TO TIME OF HEATING

Tables 3 and 4 indicate that type of burner bears a more direct relation to speed of heating than does diameter. In the group of long-chimney wick burners (Table 3, standard burners), No. 10, which is greatest in diameter, was slowest for the "cold start" test. In the group of short-chimney lighting-ring burners, No. 3, the least in diameter, was the slowest in the group, but No. 7, the greatest in diameter, was not the most rapid. The giant burner No. 9 (Table 4) is the greatest in diameter and was the slowest of the four types of giant burners. A comparison of the heating records of giant and standard burners shows that some standard burners heated more rapidly than did some giant burners on other stoves.

To determine whether speed of burners which are alike is related to diameter, tests were made on standard and giant burners on the same stove. Data are shown in Table 5.

With the exception of No. 8, the time required for heating the water was greater for the standard burners. The difference in time between Nos. 5 and 6 was less than between burners of other types; the difference in diameter is also less. The difference in time between Nos. 7 and 8 was in favor of the standard burner. This seeming inconsistency is due to the heavy grate over No. 8. When this burner was used with an open grate, it heated almost as rapidly as No. 13. No. 7 was used thruout the tests with an open grate. This burner was intended as an oven burner, but the oven was removed so that a standard burner on this stove might be studied. This explains why burners on the same stove were used with different grates.

EFFECT OF HEIGHT OF FLAME ON TIME REQUIRED FOR HEATING OF LONG-CHIMNEY BURNERS

Table 6 shows a comparison of long-chimney wick burners with flames at different heights. The difference in time for the "cold start" is almost 6 minutes in favor of the flame with yellow tips, and for the "hot start" it is over 4 minutes. Many persons using this type of burner are not aware that it can be burned with a higher flame and for this reason complain that it is slow.

TABLE 5.—*A comparison of average time required by giant and standard burners on the same stove to raise the temperature of four pounds of water from 59° F. to 208.4° F. (15° C. to 98° C.)*

Type	Burner	Diameter	Average speed of heating	
			Cold start	Hot start
		Inches	*Minutes*	*Minutes*
Long chimney with wick...........	Standard No. 12	3 3/8	15.51	13.58
	Giant No. 13	5	13.61	11.09
	Difference	1 5/8	1.90	2.49
Short chimney with lighting ring ...	Standard No. 5	4 1/8	19.25	15.61
	Giant No. 6	5	18.88	15.06
	Difference	7/8	.36	.55
Short chimney with wick..........	Standard No. 7	3 5/8	18.18	14.58
	Giant No. 8[1]	5	20.36	16.71
	Difference	1 3/8	2.18	2.13
	Giant No. 8[2]	5	14.06	11.36
	Difference	....	4.12	3.22

[1]With solid grate.

[2]With open grate.

NOTE: The stove with wickless burners has only giant burners; therefore no comparison could be made with different sized burners on this stove.

TABLE 6.—*A comparison of the average time required by long-chimney wick burners, burned with the flame kept blue and burned with yellow tips 1½ inches above the blue flame, to raise the temperature of four pounds of water from 15° C. to 98° C. (59° F. to 208.4° C.)*

Burner	Kind of Flame			
	Blue		Yellow tips 1 1/2″	
	Cold start	Hot start	Cold start	Hot start
	Minutes	*Minutes*	*Minutes*	*Minutes*
No. 1.............	20.60	18.40	15.78	14.01
No. 4.............	23.43	19.37	16.88	15.31
No. 10.............	19.80	19.35	17.24	15.06
Average........	22.61	18.98	16.63	14.79

TIME REQUIRED FOR BURNERS TO COOL

The different types of burners were found to differ in time required for cooling as well as for heating. To learn the extent of the difference, water was allowed to cool from the boiling point, and the length of time the temperature was held at boiling point before beginning to drop was determined, as well as the total drop in 30 minutes. The difference was so slight for individual burners of the same group that averages for the groups are used in the table. Results of these tests are shown in Table 7.

TABLE 7.—*Average time required for different types of burners to cool*

Type of burner	Average diameter	Time before drop in temperature began	Total drop in temperature in 30 minutes
	Inches	*Minutes*	*Degrees C.*
Long chimney with wick	3.40	5.00	14.70
Short chimney with wick	3.29	5.33	14.33
Short chimney with lighting ring	3.87	10.50	16.50
Long chimney with wick	5.00	7.50	14.00
Short chimney with wick[1]	5.00	10.00	11.50
Short chimney with lighting ring	5.00	10.00	10.00
Wickless[2]	5.75	25.00	3.00

[1]With heavy iron top.

[2]The stove with wickless burners had no standard burners.

NOTE: Room temperature during these tests ranged from 24.4° C. to 27.7° C. (76° F. to 82° F.).

Among the standard-burner groups, the wick burners cooled most rapidly, and those with long chimneys cooled slightly more rapidly than those with short. The group with lighting rings required appreciably longer to cool than other types. The flame is not extinguished in the latter type when the oil flow is turned off, but burns until the oil left in the trough is consumed. This probably explains the difference in the results for the two types of short-chimney burners.

The giant-burner types varied in time of cooling in the same way as the standard, except for the short-chimney wick burner, which seemed to cool as slowly as the type with lighting ring. The heavy iron top over the burner retains the heat, resulting in an apparent difference in heat retention for the burner. The wickless burner cooled most slowly of the four types, the greater heat retention being due to the heavily constructed iron parts, and to the flame, which continues as long as oil remains in the oil troughs after the burner is turned out.

HEATING VALUE OF DRAFT SPACES

Stoves with burners Nos. 4 and 8 have draft spaces back of the burners. These are enclosed in such a way that surplus heat is retained to be used for keeping food hot or for slow cooking. Simultaneously with some of the tests made directly on the burners, pans of water were placed over the draft spaces and comparisons made of the rise in temperature directly over the burner and over the draft space in the same period, and of the temperature of the water over the draft space at the end of 30 minutes and of one hour. The data are shown in Table 8.

The grate over No. 4 is made so that, when used right side up, there are projections raising the utensil slightly above the top of the stove. This, it is claimed, provides better heat transference to the utensil. When used upside down, the top of the grate is level with the top of the stove. Grates used over the draft spaces also provide projections above the top of the stove.

TABLE 8.—*Effectiveness of draft spaces back of burners for heating purposes*

Burner	Time required for heating water directly over flame	Rise in temperature over draft spaces	Temperature of water over draft space	
			In 30 minutes	In 1 hour
	Minutes	*Degrees C.*	*Degrees C.*	*Degrees C.*
No. 8	19.28	15	59	91
No. 4	Grate right side up 17.66	10	33	55
No. 4	Grate flat side up 21.56	30	53	81
No. 4	Solid cover over burner 30.00	46	61	94

NOTE: Temperature of four pounds of water directly over flame was raised from 15° C. to 98° C.

The draft spaces provided by these stoves are of practical significance where several foods are being cooked at the same time. Foods heated to boiling, directly over the burner, may be removed to the draft spaces for completion of cooking without additional use of oil. However, the disadvantage from the reduction of initial speed of burner No. 8, used with the heavy top, might in many cases be greater than the advantages of the draft space.

TESTS TO DETERMINE THERMAL EFFICIENCY

A kerosene stove should not only be rapid in heating action, but it should be economical in fuel requirements. To obtain information on the merits of the different burners in the latter respect, a series of tests were made in which the weight of kerosene required to evaporate four pounds of water was determined.

After preliminary adjustment of the burner to give its maximum heating effect, the kerosene tank was removed, weighed, and replaced at the same instant that the water was placed over the burner. Distilled water at 25° C. (77° F.) initial temperature was used. The boiling temperature was determined. Also the time required for the water to heat from 25° C. to the boiling point and then to evaporate completely was recorded. The instant evaporation was completed, the kerosene tank was removed and reweighed.

From the data obtained, the rate of oil consumption and the thermal efficiency were calculated, using for the latter the formula:[2]

$$\text{Thermal efficiency} = \frac{4\ (\text{boiling point}—77^\circ\ \text{F.}) + (4 \times 966)}{19{,}800 \times \text{weight of kerosene in pounds}} \times 100$$

THERMAL EFFICIENCY OF STANDARD BURNERS

The data showing thermal efficiency for all standard burners studied are shown in Table 9. The burners are grouped according to type and approximate diameter, as in Table 3.

[2] The number of British Thermal Units necessary to change a pound of water into steam is 966, and 19,800 is the heating value in British Thermal Units per pound of kerosene.

TABLE 9.—*Average time and amount of oil required by standard burners to evaporate four pounds of water initially at 25° C. (77° F.)*

Type	Burner	Diameter	Number of tests	Average time required	Probable error of mean	Total oil consumption	Oil consumption per hour	Probable error of mean	Thermal efficiency
		Inches		*Hours*		*Ounces*	*Ounces*		*Per cent*
Long-chimney burner with wick....	No. 1	3 3/8	36	1.89	±0.0236	15.16	8.00	±0.0951	23
	No. 4	3 3/8	36	3.05	±0.0991	18.51	6.05	±0.3635	19
	No. 10	3 1/2	36	2.12	±0.0211	14.74	6.93	±0.1052	24
	No. 12	3 3/8	33	1.88	±0.0978	15.14	8.03	±0.1962	23
Average of group[1]................	......	3.4	..	1.96	....	15.01	7.65	....	23
Short-chimney burner with wick....	No. 2	3 3/8	36	2.13	±0.0182	10.93	5.10	±0.0818	32
	No. 3	2 7/8	36	2.24	±0.0324	10.62	4.72	±0.0984	33
	No. 7	3 5/8	36	2.14	±0.0347	10.65	4.97	±0.1328	33
Average of group................	......	3.29	..	2.17	....	10.73	4.93	....	32.66
Short-chimney burner with asbestos lighting ring...........	No. 5	4 1/8	33	2.40	±0.0329	13.56	5.63	±0.0708	26
	No. 11	3 5/8	36	2.07	±0.0264	10.40	5.00	±0.0684	34
Average of group................	......	3.87	..	2.24	....	11.98	5.32	....	30

[1]The average for the group of long-chimney wick burners does not include No. 4.

A comparison of individual burners in the long-chimney wick-burner group shows that Nos. 1, 10, and 12 differed but little in either evaporation time or thermal efficiency. No. 10 was slightly slower than Nos. 1 and 12; however, it consumed less oil. No. 4 is exceptional and requires some explanation. As stated previously, the tests were made with all openings into the room closed. With several burners in operation at the same time, the flame on No. 4 spread apart, flickered, and finally went out. When burning alone or with windows opened, this burner performed satisfactorily. Conditions in the laboratory apparently did not affect the other burners. The performance of No. 4 indicates that the provision for draft is defective.

The records of burners in the short-chimney wick group show that there was little difference in either evaporation time or thermal efficiency.

Of the burners in the short-chimney lighting-ring group, No. 5 was considerably lower in thermal efficiency than No. 11. It was also lower in evaporation time. Differences in burner construction previously mentioned possibly affect the speed of the burners.

A comparison of averages of the different types of burners shows that there was little difference in evaporation time between groups. The long-chimney group was most rapid. The group of short-chimney wick burners was highest in thermal efficiency, but only slightly higher than the group with lighting rings. Differences in thermal efficiency between individual burners in the group with lighting rings were as great as differences between types. In considering a comparison of oil consumption of types, it should be kept in mind that the burners were at full heat at the start when the tests were made, and that they varied in time necessary for a cold burner to reach full heat after lighting.

THERMAL EFFICIENCY OF GIANT BURNERS

In Table 10 data are presented for the time required for evaporation, the oil consumption, and the thermal efficiency of the four giant burners. No. 9, a wickless burner, consumed the least oil per hour and had the highest thermal efficiency. However, the data for No. 6, a short-chimney burner with lighting ring, are very similar in all respects. No. 13, a long-chimney wick burner, consumed the most oil per hour and had the lowest thermal efficiency. At the same time, it is considerably the most rapid. The others were very similar in the latter respect. The difference between Nos. 8 and 9 in thermal efficiency is probably due to the heavy top over the former. It has been seen (Figure 5) that No. 9

TABLE 10.—*Average time and amount of oil required by standard burners to evaporate four pounds of water at 25° C. (77° F.)*

Type	Burner	Diameter	Number of tests	Average time required	Probable error of mean	Total oil con- sumption	Oil con- sumption per hour	Probable error of mean	Thermal efficiency
		Inches		*Hours*		*Ounces*	*Ounces*		*Per cent*
Short chimney with lighting ring...	No. 6	5	33	2.098	±0.0354	13.82	6.59	±0.0870	25
Short chimney with wick..........	No. 8	5	36	2.25	±0.0347	18.01	7.98	±0.1328	19
Wickless......................	No. 9	5¾	36	2.15	±0.0273	12.48	5.79	±0.1001	28
Long chimney with wick.........	No. 13	5	33	1.58	±0.0196	19.26	12.12	±0.1787	18

took longer to heat than any other type. In addition, an ounce of gasoline is required each time the burner is primed. In these tests the burner was fully heated at the start. When these facts are taken into consideration, the high thermal efficiency of the burner is of lessened significance.

TABLE 11.—*Average time required for evaporation and the oil consumption and thermal efficiency of standard and giant burners on the same stove*

Type	Burner	Diameter	Evaporation time	Total oil used	Oil used per hour	Thermal efficiency
		Inches	*Hours*	*Ounces*	*Ounces*	*Per cent*
Long chimney with wick.....	Standard No. 12	3 3/8	1.886	15.148	8.031	23
	Giant No. 13	5	1.581	19.268	12.123	18
	Difference	1 5/8	0.305	4.120	4.092	5
Short chimney with wick.....	Standard No. 7	3 5/8	2.140	10.654	4.978	33
	Giant No. 8	5	2.256	18.012	7.984	19
	Difference	1 3/8	0.116	7.358	3.006	14
Short chimney with lighting ring.........	Standard No. 5	4 1/8	2.407	13.562	5.634	26
	Giant No. 6	5	2.098	13.827	6.590	25
	Difference	7/8	0.309	0.265	0.956	1

Table 11 shows evaporation time, oil consumption, and thermal efficiency for standard and giant burners on the same stove. With the exception of Nos. 7 and 8, evaporation time was less for the giant burners. The heavy grate over No. 8 explains the apparently lower evaporation speed of this burner. The oil consumption of the giant burners was higher in all cases than the standard, and the thermal efficiency was therefore lower. There was a greater difference in thermal efficiency between Nos. 7 and 8 than between the others. Apparently the heavy top over No. 8 lowers the thermal efficiency, since that over No. 7, used with an open top, was considerably higher than the other standard burners shown in this table, and as high as any of the same type (Table 9). These data show that increase in diameter of burners on the same stove increased oil consumption and therefore lowered thermal efficiency.

OBSERVATIONS ON SOOT FORMATION

Records were kept of the frequency of soot formation on the utensils used during all the tests. The data are shown in Table 12.

TABLE 12.—*Frequency of soot formation on pans from different types of burners tested*

Type	Number of tests	Number of times soot formed	Percentage
Long chimney with wick..........	534	0	0
Short chimney with wick.........	432	271	62
Short chimney with lighting ring ..	318	192	60
Wickless........................	108	81	75

The amount of soot deposited on the pans varied, in some instances being very small, and at times covering the bottom and portions of the sides. Utensils used with long-chimney wick burners, adjusted to form yellow tips 1½ inches above the blue flame, were free from any sooty deposit. With the other types of burners, soot was formed in a large number of cases. The most frequent soot deposit was from the wickless burner, appearing 75 per cent of the times the burner was used. Since the flame on the long-chimney wick type is some distance below the utensil and is enclosed by the chimney, it is less likely to be affected by factors outside, such as draft, contact with a cold utensil, or moisture from utensils. With the other types, the flame being close to or in contact with the utensil, outside factors tend to affect it. It is difficult to adjust the flame quickly on burners with lighting rings and on wickless burners, and as a result soot is often formed before proper adjustment is obtained.

THE RELATION OF THE SIZE OF UTENSIL USED TO THE PERFORMANCE OF KEROSENE BURNERS [3]

In the studies above, the various burners were compared on the basis of their performance when heating water in ordinary aluminum pans of uniform size, such as may be found in any kitchen. Results show that for giant burners time required for heating was relatively short in comparison with that for standard burners, and thermal efficiency was relatively low. It seemed probable that the performance of any burner used with a single type of pan might not be the same when used with other sizes of pans; that is to say, that from the standpoint of speed and economy there might be one best utensil size for every burner. To learn whether the size

[3] Most helpful suggestions and criticisms were contributed to this part of the project by Prof. J. C. Russel of the Department of Agronomy, University of Nebraska.

of utensil used is an important factor in the performance of kerosene burners, and the effect upon the practical use of kerosene stoves, the following study was made.

To compare the heating speed and thermal efficiencies of burners used with different-sized utensils, a series of pans with perpendicular sides, uniformly 3½ inches deep, but varying in diameter, were constructed for use in testing the burners. It will be recalled that for all previous work in this study, aluminum pans were used. Because of the difficulty and expense of constructing aluminum pans suitable in shape and size, copper was used for the part of the study now under consideration. The diameters of the pans were as follows: 12 inches, 9.8 inches, 8.5 inches, 6 inches, 4.15 inches. To eliminate differences due to burner construction, giant and standard burners on the same stove were chosen on which to make the tests. Two additional burners on different stoves were studied because they provided extremes in diameter, and because one of the burners represented a different type from the giant-standard pairs chosen. Table 13 shows the burners used for the study.

TABLE 13.—*Numerical designation, type, and diameter of burners used*

Burner	Diameter in inches	Type
Standard No. 12	3 3/8	Long chimney with wick
Giant No. 13	5	
Standard No. 7	3 5/8	Short chimney with wick
Giant No. 8	5	
Standard No. 5	4 1/8	Short chimney with lighting ring
Giant No. 6	5	
Standard No. 3	2 7/8	Short chimney with wick
Giant No. 9	5 3/4	Wickless

The pans were all filled to the same depth (2½ inches) with distilled water, which was heated from 30° C. to 98° C. (86° F. to 208.4° F.). The pans were covered during the tests. The time for the water to heat was determined by a stop watch. The oil used to heat the water was measured. To make possible a more accurate determination of the amount of oil used than was obtainable by the method described earlier in this bulletin, the oil tank was removed and a burette graduated in cubic centimeters was suspended over the oil receptacle. The proper oil level in this receptacle having previously been established, oil was delivered from the graduated burette as required to maintain the level, and the quantity observed. The burners were adjusted as directed by the manufacturer for full heat at the beginning of each test. The tests on the various pans were conducted on each burner in successive order. The tests were made by the "hot start" method and three tests were made on each burner.

For the calculation of thermal efficiency, the formula used on page 21 was modified as follows:

$$\text{Thermal efficiency} = \frac{(\text{Wt. of water} \times 122.4) + (\text{Wt. of pan} \times 122.4^\circ \text{ F.} \times .09)}{19{,}800 \times \text{weight of kerosene in pounds}} \times 100$$

In this formula 122.4 is the temperature change in degrees F., 0.09 is the specific heat of copper, and 19,800 is the heat unit of kerosene in British Thermal Units per pound.

TABLE 14.—*Volume and weight of water used in each pan, the weight of pan, and the calculated British Thermal Units required to heat water, pan, and water plus pan from the initial temperature (30° C. or 86° F.) to the final temperature (98° C. or 208.4° F.)*

Pan diameter	Volume of water	Weight of water	To heat water	Weight of pan	To heat pan	To heat water plus pan
Inches	*Cu. inches*	*Pounds*	*B. T. U.*	*Pounds*	*B. T. U.*	*B. T. U.*
12.0	282.8	10.23	1252.2	2.50	27.5	1279.7
9.8	188.6	6.82	834.8	1.88	20.7	855.5
8.5	141.9	5.14	629.1	1.54	16.9	646.0
6.0	70.7	2.56	313.3	0.96	10.7	323.8
4.15	33.9	1.23	150.6	0.62	6.8	157.4

Tables 15, 16, 17, and 18 show the weights of kerosene required with calculated thermal efficiencies, and the total time per pan and per pound of water heated.

The thermal efficiencies and time required to heat per pound are shown graphically in Figure 6 in relation to the cross-sectional area of the pan.

TABLE 15.—*Oil required by standard and giant long-chimney wick burners to heat water in the series of pans, thermal efficiency, total time of heating water, and time per pound of heating*

Burner	Pan diameter	Oil used to heat	Thermal efficiency	Time required to heat water	
				Total minutes	Minutes per pound
	Inches	*Pounds*	*Per cent*		
Standard—No. 12 Diameter 3 3/8 inches	12.0	.2066	31.2	22.35	2.18
	9.8	.1348	32.0	16.43	2.40
	8.5	.1114	29.2	14.68	2.85
	6.0	.0665	24.5	8.95	3.49
	4.15	.0449	17.7	6.05	4.91
Giant—No. 13 Diameter 5 inches	12.0	.2606	24.8	20.13	1.96
	9.8	.1897	22.7	14.93	2.18
	8.5	.1492	21.8	12.98	2.52
	6.0	.0863	18.9	7.96	3.10
	4.15	.0619	12.8	5.86	4.76

TABLE 16.—*Oil required by standard and giant short-chimney wick burners to heat water in the series of pans, thermal efficiency, total time of heating water, and time per pound of heating*

Burner	Pan diameter	Oil used to heat	Thermal efficiency	Time required to heat water	
				Total minutes	Minutes per pound
	Inches	*Pounds*	*Per cent*		
Standard—No. 7 Diameter $3\frac{5}{8}$ inches	12.0	.1635	39.5	25.08	2.45
	9.8	.1078	40.1	17.06	2.50
	8.5	.0809	40.3	14.51	2.82
	6.0	.0468	34.9	9.06	3.53
	4.15	.0305	26.0	6.68	5.43
Giant—No. 8 Diameter 5 inches	12.0	.1761	36.7	20.70	2.11
	9.8	.1258	34.3	14.45	2.10
	8.5	.0970	33.6	12.30	2.39
	6.0	.0611	26.7	8.08	3.15
	4.15	.0467	17.0	5.68	4.61

NOTE: For these tests, burner No. 8 was used with an open grate. It will be recalled that this burner as purchased is covered with a heavy, solid grate.

TABLE 17.—*Oil required by standard and giant short-chimney lighting-ring burners to heat water in the series of pans, thermal efficiency, total time of heating water, and time per pound of heating*

Burner	Pan diameter	Oil used to heat	Thermal efficiency	Time required to heat water	
				Total minutes	Minutes per pound
	Inches	*Pounds*	*Per cent*		
Standard—No. 5 Diameter 4 1/8 inches	12.0	.1708	37.8	22.40	2.18
	9.8	.1042	41.4	16.45	2.41
	8.5	.0791	41.2	13.75	2.67
	6.0	.0449	36.4	8.56	3.34
	4.15	.0306	25.9	6.33	5.14
Giant—No. 6 Diameter 5 inches	12.0	.1797	35.9	21.31	2.08
	9.8	.1258	34.3	15.13	2.07
	8.5	.0971	33.6	12.71	2.47
	6.0	.0611	26.7	7.56	2.95
	4.15	.0431	18.4	5.00	4.06

TABLE 18.—*Oil required by each burner to heat water in the series of pans, thermal efficiency, total time of heating water, and time per pound of heating*

Burner	Pan diameter	Oil used to heat	Thermal efficiency	Time required to heat water	
				Total minutes	Minutes per pound
	Inches	*Pounds*	*Per cent*		
Standard, short-chimney burner—No. 3 Diameter, 2 7/8 inches	12.0	.1617	39.9	31.98	3.12
	9.8	.0989	43.6	20.30	2.97
	8.5	.0809	40.3	15.93	3.09
	6.0	.0485	33.7	9.80	3.82
	4.15	.0306	25.9	5.96	4.84
Giant wickless burner—No. 9 Diameter 5 3/4 inches	12.0	.1564	41.3	25.10	2.45
	9.8	.1043	41.4	18.78	2.75
	8.5	.0845	38.6	16.23	3.15
	6.0	.0450	36.3	11.28	4.40
	4.15	.0306	25.9	8.50	6.91

The data in the four tables and in Figure 6 indicate very definitely two conclusions in regard to the effect of the size of the utensil. First, as diameter increases, from the smallest to the largest, the thermal efficiency increases rapidly at first, for the smaller diameters, and then less rapidly, and becomes a maximum at the largest (12-inch) or next to the largest (9.8-inch) size. Where the burner was small (standard), the maximum thermal efficiency was attained at a pan diameter of 9.8 inches; however, the increase in efficiency over that at 8.5 inches is not large. Where the burner was large (giant), the highest thermal efficiency was obtained in these studies at the largest diameter. The maximum efficiencies for giant burners is probably to be obtained with a somewhat larger pan. In half the cases, thermal efficiency was twice as high for the largest as for the smallest pan used. Second, as diameter increases, the time required to heat a unit quantity of water decreases, rapidly at first for the smaller diameter, then less rapidly and becomes a minimum at the largest or next to the largest diameter used. In all but one case, it took over twice as much time to heat a

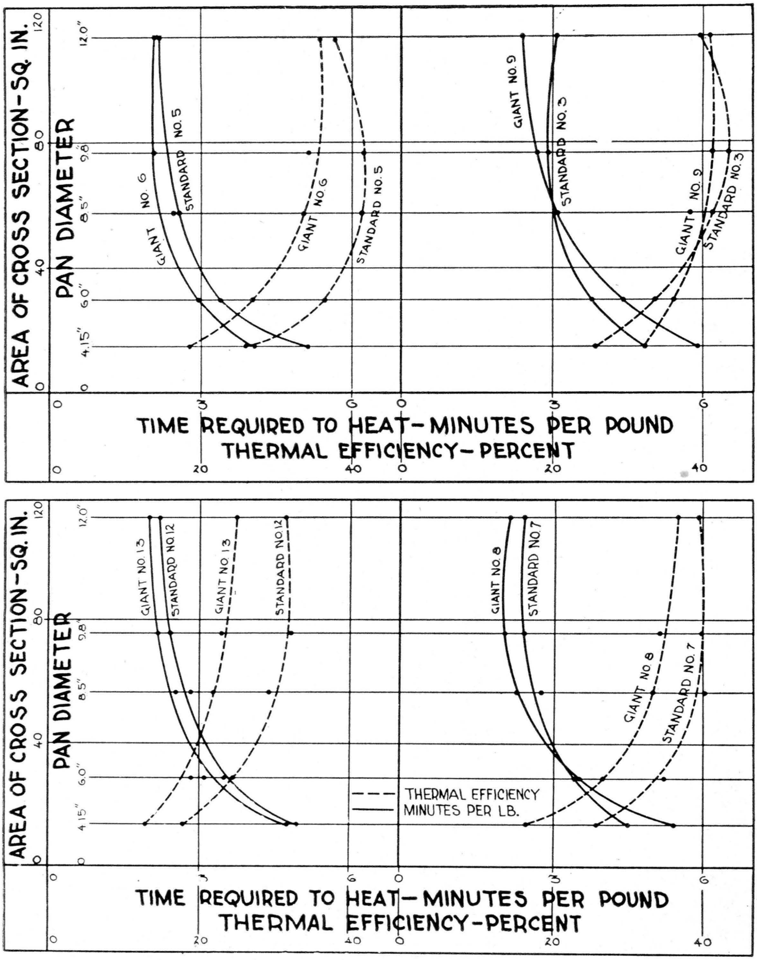

FIGURE 6.—Thermal efficiency and time required to heat water expressed in minutes per pound, in relation to cross sectional area of pan.

pound of water from 30° to 98° C. in a 4.15-inch pan as in a 12-inch pan.

The practical significance of these conclusions is that for each size and type of burner there is a definite size of utensil which can be used to the best advantage. For burners in general, utensils should be fairly large.

In Table 19 the data in Tables 15 to 18 are analyzed to show the performance of the different burners on a relative

TABLE 19.—*Relative thermal efficiency and relative time of heating per pound of water in relation to utensil size expressed as percentage of the values obtained on standard No. 7*

	Pan diameter	Short-chimney wick burner		Long-chimney wick burner		Short-chimney lighting ring		Standard short chimney No. 3	Giant wickless No. 9
		Standard No. 7	Giant No. 8	Standard No. 12	Giant No. 13	Standard No. 5	Giant No. 6		
	Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Relative thermal efficiency	12.0	100	93	79	63	96	91	101	104
	9.8	100	86	80	57	103	86	109	103
	8.5	100	83	72	54	102	83	100	96
	6.0	100	76	70	54	104	76	97	104
	4.15	100	65	68	49	100	71	100	100
	Mean	100	80.6	73.8	55.4	101	81.4	101.4	101.4
Relative time of heating	12.0	100	86	89	80	89	85	127	100
	9.8	100	84	96	87	96	83	119	110
	8.5	100	85	101	89	95	88	110	112
	6.0	100	89	99	88	95	84	108	125
	4.15	100	85	90	88	95	75	89	127
	Mean	100	85.8	95.0	86.4	94.0	83.0	110.6	114.8

basis, when different sizes of pans are used. Standard burner No. 7 was chosen, after inspection of the data, as a basis for comparison.

It is to be observed that the relative performance of the different burners is very satisfactorily constant for the different sizes of pans in some cases, but not in others. In those cases where the relative performance is not constant, the most erratic values were obtained with the smaller pans. In all cases the mean performance is close to that obtainable by an 8- to 10-inch pan.

In Table 20 a comparison is shown of time of heating and thermal efficiency data obtained with 6¾-inch aluminum pans, with the data obtained with copper pans as presented in

TABLE 20.—*The relative performance of kerosene burners when tested with aluminum and copper utensils*

Burner number	Relative time of heating per pound of water		Thermal efficiency			
			Relative		Absolute	
	Aluminum pans[1]	Copper pans	Aluminum pans[1]	Copper pans	Aluminum pans[1]	Copper pans[4]
7	100.0	100.0	100.0	100.0	33	34.9
8	78.0[2]	86.1	57.6[3]	93.0[2]	19[3]	26.7[2]
12	93.2	89.0	69.7	79.0	23	24.5
13	76.0	80.0	54.5	63.0	18	18.9
5	107.0	89.0	78.8	96.0	26	36.4
6	103.3	85.0	75.8	91.0	25	26.7
3	106.6	127.0	100.0	101.0	33	33.7
9	111.4	100.0	84.9	104.0	28	36.3

[1]6¾-inch diameter.
[2]Data for tests with open top.
[3]Data for tests with a solid grate over burner.
[4]6-inch diameter.

Table 19. The data for the aluminum pans are reduced to a relative basis using the values shown in Tables 3, 4, 9, and 10 and standard burner No. 7 as a basis for comparison. It is to be observed that fairly satisfactory agreement between the data for aluminum and copper is shown in most cases. On the basis of relative time of heating, burners Nos. 5 and 6 are the only ones that seriously fail to correspond in general ranking. On the basis of thermal efficiency, burners Nos. 5 and 9 fail to correspond.

Considering the numerous replications of tests and the low value of the probable errors shown in Tables 3, 4, 9, and 10, it is believed that the comparative performance of the various burners based on studies with uniform aluminum utensils is a reliable indication of the merits of individual burners and burner types. The fact that somewhat different indications of merit were obtained with copper pans, shows clearly the importance of taking into consideration the character of utensils used in burner and cooking studies. Possibly not only the size, but also the shape and material are factors in burner performance.

PRACTICAL COOKING TESTS [4]

From an engineering standpoint, tests of stoves made under uniform laboratory conditions, giving data by which the performance of the various types may be compared, are probably of most significance. However, such data, while valuable, do not include information in regard to many features of practical importance. It is essential to know how the stoves compare in heating action, cost of operation, quality of cooked product, and convenience, when used for the actual cooking of food.

To obtain data which could be made a basis for such comparison, standard menus for one week were cooked on four selected stoves representing each type of burner. The menus were based on records obtained from Nebraska farm women, the aim being to choose products which were fairly typical of those prepared in farm homes and, at the same time, provide a fair test for the performance of the burners. The meals were prepared in quantities for six persons. All food used was weighed or measured. The water for dish washing was heated from 15° C. to 98° C. (59° F. to 208.4° F.). The burners on each stove were of equal diameter. The time each one was in operation was recorded by a stop watch. Timing began with the lighting of the cold burner. Burners were turned out when not in use. An attempt was made to cook the food with the least possible use of time and oil. The burners were operated thruout by one person, so that variations in judgment as to whether food was done might be reduced to a minimum. The oil tanks were weighed at the beginning and end of each day to determine the oil consumption. The same utensils were used thruout. All baking was done in a selected portable oven. The oven was ventilated and interlined with asbestos. At the top of the oven was a "Baker's Arch", or arched baffle plate, a feature which, it is claimed, sends the heat downward over the food, producing a more evenly baked product. At the bottom of the oven was a patented heat distributor, lined with asbestos and covered with porcelain enamel. The outside dimensions of

[4] Menus, amounts of food, and description of utensils used will be found on page 40.

TABLE 21.—*Time in burner hours and cost of operation for cooking a week's menus for six persons on four selected stoves representing four types of burners*

	Burner No. 1, long chimney with wick		Burner No. 3, short chimney with wick		Burner No. 5, short chimney, asbestos ring		Burner No. 9, wickless		
	Time used each day	Oil used each day	Time used each day	Oil used each day	Time used each day	Oil used each day	Time used each day	Oil used each day	Gasoline used
	Burner hours	*Gallons*	*Burner hours*	*Gallons*	*Burner hours*	*Gallons*	*Burner hours*	*Gallons*	*Gallons*
1.	10.5	.854	11.6	.507	13.2	.723	10.9	.517	.0735
2.	11.2	.710	10.7	.751	10.2	.567	13.7	.633	.1103
3.	11.1	.723	10.7	.712	11.5	.687	13.9	.792	.0827
4.	12.1	.704	12.4	.585	10.8	.682	13.2	.831	.1103
5.	10.0	.723	11.3	.597	12.4	.737	11.8	.663	.1194
6.	12.0	.845	9.8	.512	10.7	.694	10.4	.584	.0827
7.	10.4	.675	12.3	.641	9.0	.547	11.5	.520	.0827
TOTAL FOR WEEK'S MEALS									
	77.3	5.234	82.9	4.305	77.8	4.637	85.4	4.540	.6616
TOTAL COSTS									
Of oil per week		$ .74		$ .61		$ .65			$ .64
Of wicks		.068		.092		.051	Primer (gasoline)		.12
Total		$ .81		$ .71		$ .71			$ .76

Wicks on burner No. 1 last approximately 375 hours and cost 3 for $1.00.
Wicks on burner No. 3 last approximately 300 hours and cost 3 for $1.00.
Lighting rings on burner No. 5 last approximately 150 hours and cost 10 cents each.

Kerosene @ 14 cents per gallon.
Gasoline @ 18 cents per gallon.
Four and one-half gallons of water was heated each day for dishes.

the oven were 20 inches from front to back, 16¾ inches in height, and 15¼ inches in width. The foods baked were placed as near the center as possible, on a grate, and a thermometer was used so that uniform temperatures could be obtained before placing food in the oven.

The data showing time and cost of operation are shown in Table 21.

The long-chimney burner and the short chimney with asbestos lighting ring required less time than the other types, these burners differing only slightly. The wickless burner was slowest. With the exception of the long-chimney burner, which required the most, there was little difference in the amount of kerosene used. The ranking of the burners as to time and oil requirement, shown in Table 21, is fairly consistent with that for the same burners shown in Tables 3 and 4, and 9 and 10. In the previous studies, however, the long-chimney burner was more rapid than the short chimney with lighting ring. It should be kept in mind that determinations made as in the previous tables would be subject to fewer errors than those in the practical studies. The total costs of operation for the four burners in the cooking tests vary with the relative cost of wicks, lighting rings, and gasoline for priming the wickless burner. The total cost with the long-chimney wick burner was highest, and with the wickless slightly less. It is probable that over a long period of time the long-chimney burner would vary little from the others in fuel consumption, since it is at full heat very soon after lighting. The other types require a longer time to reach full heat, and in addition the wickless burner, which is the slowest, must be primed. Rather than wait to reheat a short chimney or a wickless burner, many persons would allow them to burn when not in use. The long-chimney burner is quickly and easily turned out and relighted. During a large number of cooking processes of short duration, there would probably be less tendency to waste oil with a long-chimney burner.

The quality of foods cooked on the four types of burners was, on the whole, quite satisfactory. Vegetables, which require high temperatures, were, on all types of burners, palatable and attractive in appearance. Allowing for differences in original quality, steaks cooked on the different types of burners were more uniform in quality than meats requiring long cooking at lower temperatures. The types of burners varied in their capacity to maintain low-temperature cooking. On the wick burners with both long and short chimneys, the flame could be lowered sufficiently to maintain simmering heat. The flames of the short chimney with asbestos lighting ring and of the wickless burner could not be adjusted to maintain temperatures below boiling after the burners were heated thru. Ham, beef, and chicken were cooked in an iron kettle or "Dutch oven". The product was more tender when cooked on the burners which could be easily and quickly adjusted for low heat. The short chimney with asbestos lighting ring was most difficult to adjust. It is probable that by using extra grates and asbestos pads under the cooking utensil, the heat could be regulated. However, the burner which can be adjusted without additional pieces of equipment is more desirable from the standpoint of the user.

The difficulty of regulating temperature was again apparent in the use of the oven. Foods requiring quick baking at high temperatures, such as biscuits, muffins, cookies, and some pies, were of good quality, while loaf cakes and roasts, which require slow baking, were less desirable in quality. By the use of one burner, with the lighting-ring and wickless types, after the oven was heated, satisfactorily low oven temperatures were maintained, but there was always the disadvantage of slow adjustment of flame in these burners.

MENUS, AMOUNTS, AND UTENSILS USED IN PRACTICAL COOKING TESTS ON DIFFERENT TYPES OF BURNERS

Menus	*Amounts*
1. Breakfast Biscuits Soft boiled eggs Coffee	flour, 1 lb. fat, 3 oz. milk, 1½ cup coffee, 2 oz. water, 3 lbs. eggs, 6 water, 2 lbs.
1. Lunch Scalloped potatoes with tuna fish Buttered peas Baked apples Tea	potatoes, 3 lbs. tuna, 1 lb. peas, 2½ lbs. milk, 2 cups fat, 4 tbsp. flour, 4 tbsp. water (for potatoes), 2 lbs. apples, 6 medium water, ½ cup water for tea, 4 lbs.
1. Dinner Pan broiled stake Mashed potatoes Gravy Spinach Cherry pie Coffee	potatoes, 3 lbs. steak, 1½ lbs. liquid for gravy, 1 pt. spinach, 1 lb. 4 oz. (canned) flour, ½ lb. fat, ⅜ lb. cherries, 1¼ lbs. coffee, 2 oz. water, 3 lbs.
2. Breakfast Baked apples Toast Oatmeal Poached eggs Coffee	bread, 14 oz. oatmeal, 1½ oz. water, 1½ lbs. water (for double boiler), 3 lbs. eggs, 6 water, 1 lb. apples, 6 medium water, ½ cup
2. Lunch Fried potatoes Bacon Muffins (whole wheat) Rice pudding Tea	bacon, ½ lb. potatoes, 3 lbs. rice, ⅓ cup water, 2 lbs. whole wheat, ½ lb. flour, ¼ lb. fat, 2 oz. milk, 1½ cups water (for tea), 4 lbs.

Menus	*Amounts*
2. Dinner Ham Browned sweet potatoes Stewed apples Beets Caramel cake Coffee	ham, 3 lbs. potatoes, 3 lbs. apples, 6 medium beets, 1¼ lbs. (canned) flour, ⅜ lb. water, ½ cup sugar, ⅜ lb. fat, ⅛ lb. caramel syrup coffee, 2 oz. water, 3 lbs.
3. Breakfast Toast Omelet (egg) Coffee	bread, 14 oz. eggs, 6 coffee, 2 oz. water, 3 lbs.
3. Lunch Baked salmon Tomato sauce Boiled potatoes Cake with sauce Tea	salmon, 1 lb. potatoes, 3 lbs. tomato pulp, 1 lb. milk, 1 cup chocolate, 1 square cornstarch, 2 tbsp. sugar, ¼ lb. water (for tea), 4 lbs.
3. Dinner Baked pork chops with dressing Browned parsnips Baked potatoes Apple pie Coffee	pork chops, 6 bread (for dressing), 12 oz. parsnips, 2 lbs. potatoes, 6 medium apples, 2 lbs. flour, ½ lb. fat, ⅜ lb. coffee, 2 oz. water, 3 lbs.
4. Breakfast Toast Bacon and eggs Coffee	bacon, ½ lb. bread, 14 oz. eggs, 6 coffee, 2 oz. water, 3 lbs.
4. Lunch Creamed dried beef on toast Buttered cabbage Apple tapioca Tea	dried beef, ¾ lb. milk, 2 cups butter, 1½ oz. cabbage, 3 lbs. water, 2½ lbs. apples, 1 lb. water, 1½ lbs. tapioca, 6 tbsp. sugar, ¼ lb. water (for tea), 4 lbs.

Menus	*Amounts*
4. Dinner Fried chicken Riced potatoes Gravy Cranberry sauce Chocolate cake	chicken, 4 lbs. potatoes, 3 lbs. liquid for gravy, 2 cups cranberries, 1 lb. flour, ⅓ lb. sugar, ½ lb. milk, ½ cup flavoring
5. Breakfast Wheatena Bacon Eggs Coffee	wheatena, 4 oz. water, 2 lbs. water in double boiler, 3 lbs. bacon, ½ lb. eggs, 6 coffee, 2 oz. water, 3 lbs.
5. Lunch Baked stuffed potatoes with cheese Creamed onions Gingerbread Tea	potatoes, 6 medium onions, 2 lbs. milk, 3 cups fat, 2 oz. flour, ⅓ lb. water, ½ cup molasses, 6 oz. fat, ⅛ lb. sugar, ¼ lb. egg, 1 spices water (for tea), 4 lbs.
5. Dinner Meat stew with potatoes, carrots, cabbage onions, celery Apple pudding Coffee	beef (chuck), 2 lbs. vegetables, 4 lbs. apples, 3 lbs. flour, ⅕ lb. milk, ¼ cup egg, 1 fat, 1⅓ oz. coffee, 2 oz. water, 3 lbs. flavoring
6. Breakfast Waffles Syrup Coffee	flour, 1 lb. fat, 1 oz. milk, 3 cups eggs, 4 coffee, 2 oz. water, 3 lbs.

Menus	*Amounts*
6. Lunch Macaroni and cheese Green beans Chocolate cornstarch pudding Tea	macaroni, 16 oz. cheese, ½ lb. milk, 2 cups fat, 2 oz. beans, 2½ lbs. milk, 3 cups cornstarch chocolate, 1½ squares sugar, ¼ lb. water in double boiler, 2 lbs.
6. Dinner Pot roast of beef with carrots and potatoes Gravy Peach short cake Coffee	meat (rump), 3 lbs. potatoes, 3 lbs. carrots, 2¼ lbs. peaches, 1¼ lbs. liquid for gravy, 1 lb. flour, ¾ lb. sugar, ⅛ lb. fat, ⅕ lb. coffee, 2 oz. water, 3 lbs.
7. Breakfast Griddle cakes Sausage Syrup	sausage, 1½ lbs. flour, 1 lb. fat, 1 oz. milk, about 3½ cups sugar for syrup, 1 lb. water, 1 cup coffee, 2 oz. water, 3 lbs.
7. Lunch Creamed eggs Stewed corn Cookies Tea	eggs, 7 milk, 3 cups fat, 2 oz. flour, 6 tbsp. corn, 2½ lbs. flour, ½ lb. fat, 5 tbsp. sugar, ½ lb. spices and raisins water (for tea), 4 lbs.
7. Dinner Meat loaf Scalloped potatoes Cabbage parboiled and cooked with meat Lemon pie	meat: beef, 2 lbs. pork, 1 lb. cabbage, 2 lbs. potatoes, 3 lbs. milk, 3 cups fat, 3 oz. water for potatoes, 3 lbs. flour, ¼ lb. fat, 3/16 lb. sugar, ⅜ lb. lemon, 1 water, 1¼ lbs. eggs, 3 coffee, 2 oz. water, 3 lbs.

Utensils Used for Cooking Different Foods

Aluminum baking sheet for biscuits and cookies.
Earthen casserole for scalloped potatoes, baked pork chops, scalloped eggs, salmon, macaroni and cheese.
Cast iron skillet for poaching eggs, making omelet, pan broiling steak, and frying eggs, bacon, sausage, and parsnips.
Aluminum roaster with Pyrex cover for meat loaf.
Iron kettle, "Dutch oven," for stew, beef roast, chicken, and ham.
Aluminum pans (flat bottomed) for all vegetables and fruits.
Tin muffin pans.
Pyrex for cakes, puddings, and pies.
Aluminum double boiler for cereal, lemon filling, and sauces.
Iron waffle iron.
Aluminum tea kettle for heating dish water.
Volrath enamel coffee percolator.

[2M]